A STUDY ON THE DISCHARGE OF CONDENSER USING A TRANSISTORIZED BLOCKING OSCILLATOR

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ABSTRACT The problem of discharge of a condenser with the help of a transistorized blocking oscillator is investigated, both the grounded base and the grounded emitter mode of operation being considered. The optimum turns ratio of the feedback transformer for maximum discharge has been found out. Expressions for voltage swing are found out by theoretical analysis and confirmed by experimental measurements. A comparison of the relative merits of the grounded base and the grounded emitter modes reveals that a larger voltage swing should be obtainable with the latter mode; however, conditions requiring optimum performance of the grounded emitter mode cannot be realised in practice. A versatile generator of staircase waveform which may find use in special fields of application has also been incidentally developed.

INTRODUCTION

Transistorized blocking oscillators have been used as generators of rectangular pulses (Wrathall, 1956 and Tendick, 1956), pulse lengtheners and pulse frequency dividers (Butler, 1959). Linvill and Mattson (1955) have shown that a blocking oscillator using a junction transistor of a few megacycles alpha cut-off frequency could be used to obtain fast risetime by a proper choice of the feedback transformer.

In pulse techniques, ordinary blocking oscillators are frequently used for discharging a condenser (Chance *et al.*, 1949). The potentiality of a transistorized blocking oscillator as a means for such discharge has not, however, been investigated uptill now. In the present paper an account is given of such an investigation using both the grounded-base and grounded emitter configurations of the oscillator. The general principle of operation of a transistorized blocking oscillator is first described. This is followed by a theoretical analysis of the two modes of operation in Sec. 3. The results are extended in Sec. 4 to include the effect of delay caused by the transistor on the discharge of the condenser. Relative merits and demerits of the two modes of operation are critically examined in Sec. 5. The voltage swing due to discharge is shown to be larger with the grounded emitter mode. For both the modes, the transformer requirements for optimum discharge of a condenser are calculated. It is found that these requirements are different from those derived for minimum pulse rise-time by Linvill and Mattson. Thus, with a transformer designed to ensure the maximum discharge of a condenser, the speed of switching of the blocking oscillator would be somewhat sacrificed.

A free running blocking oscillator as a medium of condenser discharge is described in Sec. 6. It is shown that such a circuit arrangement may be designed in a manner so as to function as a generator of staircase waveform. Experimental evidences in support of results obtained in Sec. 3-6 are presented in Sec. 7.

TRANSISTORIZED BLOCKING OSCILLATOR AND ITS USE FOR CONDENSER DISCHARGE

The basic blocking oscillator circuit of the grounded base mode considered by Linvill and Mattson is shown in Fig. 1. It can either be triggered or free running depending upon the value of V_r. In either case, the oscillator possesses three distinct states, viz., the OFF, the regenerative and the ON states. Let us consider a triggered oscillator. In the OFF state the transistor and the diode D_1 and D_2 are non-conducting and the collector is at a potential (V_1+V_2). With a triggering pulse applied, the emitter begins to draw current. This produces a collector current which in turn sends a larger emitter current because of the regenerative feedback via the transformer T. This constitutes the regenerative state of the oscillator. During this period the collector potential falls steadily until it reaches a value V_1. At this state D_1 begins to conduct and the collector potential is clamped to the value V_1 –hole storage effect being thus eliminated. This latter is the primary function of D_1. Since the collector potential no longer changes after this state, further regeneration is stopped and the second state is, therefore, complete. After this the transistor is in the third state, viz., the ON state. The voltage source V_2, however, tends to send through the magnetising

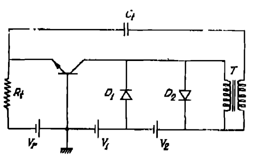


Fig. 1. Blocking oscillator circuit.

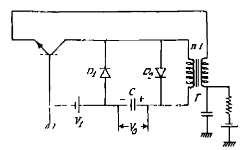


Fig. 2. Blocking oscillator circuit discharging a condenser

inductance of the transformer a current that increases almost linearly with time. This current is in a direction opposite to that in D_1. Hence, the current through D_1 is gradually transferred, as it were, to the magnetising inductance until it becomes non-conducting again. After this the collector voltage begins to rise causing a regenerative cycle leading to a rapid transition of the oscillator towards the OFF state. After the collector has attained the value (V_1+V_2) the diode D_2 prevents any further rise, thus protecting the transistor against a high reverse bias. The cycle of operation is then complete. The oscillator continues in the OFF state till a fresh cycle is initiated by another pulse. If instead of a battery V_2 we have a condenser C charged to V_2 then the same cycle as above will be traced upon application of a triggering pulse.

For the free running case, the OFF state is reached because of the charges stored in the condenser C_t. A fresh cycle starts when this has been discharged via R_t to an extent so as to bias the emitter-base junction in the forward direction.

ANALYSIS OF THE TRANSISTOR BLOCKING OSCILLATOR OPERATION

In the present section simple analysis of the operation of a blocking oscillator will be given for both the grounded base and the grounded emitter mode of operation. The line of treatment will follow closely that of Linvill and Mattson. We shall first consider the grounded base configuration.

(a) *Grounded base configuration*

The essential details of a transistor blocking oscillator operating in the grounded base mode is shown in Fig. 2, where C is the condenser to be discharged by the oscillator. Didoes D_1 and D_2 perform the same functions as described already in the preceding section. T is the feedback transformer with a turns ratio of n . 1. C is initially charged to the potential V_0 During the process of charging, the blocking oscillator is in the OFF state, the discharge is initiated by switching it into the ON-state with the help of a triggering pulse. Alternatively, the blocking oscillator may be a free-running one allowing periodic charging and discharging of the condenser C. It will be convenient to consider separately the conditions during the regeneration and the ON-state of the oscillator.

(i) *Oscillator at the regenerative or the switch-on time* . At the regenertaive or the switch-on time the circuit is unstable. Linvill and Mattson assumed that once the emitter is forward-biased, the circuit behaves in an essentially linear manner. Now the capacitance C, with the voltage V_0 across it, may be treated as a voltage source V_0 at this instant. Analysis of this period would, therefore, be the same as that given by Linvill and Mattson. The equivalent circuit given by them is reproduced in Fig. 3 in which the symbols have the following meanings

C_c = collector to base capacitance, r_b = base resistance, L_e = leakage inductance = $(1-k^2)L_m$, L_m = magnetising inductance of the transformer, k = coefficient of coupling and i_a = equivalent current generator. In this equivalent circuit the emitter resistance and the collector conductance have been assumed

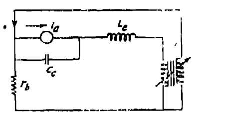
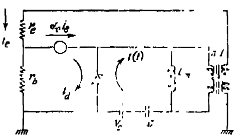


Fig. 3. Blocking oscillator equivalent circuit at switch-on time.



Ideal transformer.

Fig. 4. Equivalent circuit of the blocking oscillator during the ON period.

to be negligible and the low frequency short circuit current unity. Further, both the diodes D_1 and D_2 are considered to be open circuit.

Starting with the characteristic equation, giving the natural frequencies of the equivalent circuit of Fig. 3, these authors have shown that the magnetising inductance L_m is related to the turns ratio n and the coefficient of coupling k as

$$L_m = \frac{-\frac{(n-1)^2}{g_b\omega_{ab}}\cdot x^2 - \left[\frac{(n-1)}{g_b\omega_{ab}} + \frac{1}{\omega_{ab}^2C_c}\right]\cdot x + \frac{(n-1)}{C_c\omega_{ab}}}{(1-k^2)x^3+(1-k^2)x^2}, \quad \ldots (1)$$

where $x = \frac{p}{\omega_{ab}}$ = the ratio between the positive real root of the characteristic equation of the circuit and the common base angular cut-off frequency of the transistor, and

$$g_b = \frac{1}{r_b}$$

The fastest speed of operation requires the highest possible value of x. The highest attainable value of x is, however, limited by the fact that L_m must always be positive. Basing arguments around this requirement Linvill and Mattson have given the following relation giving the value of turns ratio requred for a given x or speed of response.

$$n = n_m = 1 + \frac{g_b}{2C_c\omega_{ab}(x^2+x)}. \quad \ldots (2)$$

For a transistor having $r_b = 100$ ohms, $C_c = 10$ pf, $\omega_{ab} = 2\pi\times 3.5\times 10^6$, eqn.(2) gives for $x = 2$ (maximum permissible for L_m positive),

$$n_m \simeq 5. \quad \ldots (3)$$

This means that with a transistor of 3.5 Mc/s cut-off frequency one can get as low a rise-time as 0.1μ sec. by using a transformer turns ratio 5.

(ii) *Oscillator during the ON period* : After the oscillator has been switched on, the equivalent circuit takes the form as shown in Fig. 4 provided the effects of C_c, L_e and diffusion delay are negligible. This is the same circuit as derived by Linvill and Mattson excepting for the inclusion of the condenser C in the arm containing V_0. When the oscillator is switched on, diode D_1 presents a short circuit, D_2 an open circuit and the voltage V_0 appears directly across the combination L_m and C. Applying the operational method to the loop containing these elements we have,

$$I(p) = \frac{V_0/p}{pL_m+1/pc} = CV_0 \cdot \frac{1}{\sqrt{L_mC}} \cdot \frac{1/\sqrt{L_mC}}{p^2+1/L_mC}$$

or,
$$i(t) = V_0\sqrt{\frac{C}{L_m}} \sin \omega t, \qquad \dots (4)$$

where
$$\omega = \frac{1}{\sqrt{L_mC}}. \qquad \dots (5)$$

The voltage waveform across the condenser is then given by

$$V_c = V_0 + \frac{\int_0^t i(t)dt}{C}$$

or,
$$V_c = V_0 \cos \omega t. \qquad \dots (6)$$

The diode current i_d is then obtained as

$$i_d = \frac{V_0 \cos \omega t}{n[r_e+r_b(1-\alpha_0)]} \left(\alpha_0 - \frac{1}{n}\right). \qquad \dots (7)$$

The first factor on the right hand side of the equation is the emitter current at any instant. i_d is then the difference between the currents flowing through the collector and the emitter referred to the primary side of the transformer

When i_d has been transferred to L_m, the ON condition is terminated and the discharge stopped. This evidently happens when $i(t) = i_d$. This last condition determines the pulse duration τ. Putting $t = \tau$ in eqns. (4) and (7), we get,

$$V_0 \sqrt{\frac{C}{L_m}} \sin \omega\tau = \frac{V_0 \cos \omega\tau}{n[r_e+r_b(1-\alpha_0)]} \left(\alpha_0 - \frac{1}{n}\right),$$

or,
$$\tan \omega\tau = \sqrt{\frac{L_m}{C}} \cdot \frac{(\alpha_0 n-1)}{n^2[r_e+r_b(1-\alpha_0)]_b}. \qquad \dots (8)$$

The voltage V_c across C at time τ is of course given by,

$$V_{c\tau} = V_0 \cos \omega\tau, \qquad \dots (9)$$

according to eqn. (7), and the voltage swing or the amplitude of discharge by,

$$A = V_0(1-\cos \omega\tau). \qquad \dots (10)$$

From eqns. (8) and (10), we readily obtain,

$$A = V_0 \left[1 - \frac{1}{\left[1 + \frac{L_m}{C} \left[\frac{(\alpha_0 n - 1)}{n^2[r_e + r_b(1-\alpha_0)]} \right]^2 \right]^{\frac{1}{2}}} \right]. \quad \ldots (11)$$

Referring back to eqns. (8) and (9), it is clear that the maximum discharge of C should be obtained if the transformer turns ratio be so chosen as to maximise the value of tan $\omega\tau$. For the latter condition to be satisfied

$$\frac{\partial}{\partial n} (\tan \omega\tau) = 0$$

or,

$$\frac{\partial}{\partial n}\left[\sqrt{\frac{L_m}{C}} \cdot \frac{(\alpha_0 n - 1)}{n^2[r_e + r_b(1-\alpha_0)]} \right] = 0,$$

giving,

$$n = n_{max} = \frac{2}{\alpha_0}. \quad \ldots (12)$$

Taking,

$$\alpha_0 \simeq 1,$$

$$n_{max} = 2. \quad \ldots (13)$$

Referring to eqns.(2) and (3) we find that this value of n is very much different from that required for the speed of switching determined by the condition $x = 2$. Also, unlike the latter case, α_0 is the single transistor parameter that determines the optimum value of n for maximum discharge of condenser. Since α_0 may be taken to be unity for all practical junction transistors the optimum value of n should be sensibly independent of the type of transistor used and is roughly equal to 2.

Substituting (12) in (11), the amplitude of discharge for optimum turns ratio is found to be,

$$A = V_0 \left[1 - \frac{1}{\left[1 + \frac{L_m}{C} \left[\frac{\alpha_0^2}{4[r_e + r_b(1-\alpha_0)]} \right]^2 \right]^{\frac{1}{2}}} \right]. \quad \ldots (14)$$

It may be seen from (11) and (14), that the higher is the value of L_m/C and lower is the transitor input resistance, the more complete is the discharge of of the condenser.

(b) *Grounded emitter configuration*

Analysis of the grounded emitter configuration of the blocking oscillator is essentially the same as that for the grounded base mode. As before we shall again consider separately the regenerative and the ON state of the oscillator.

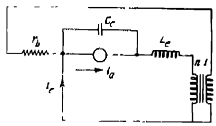


Fig. 5. Grounded emitter equivalent circuit at the switch-on time of the blocking oscillator

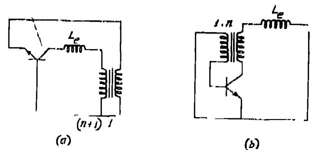


Fig 6 Correspondence between grounded base and grounded emitter mode of operation.
(a) Grounded base mode
(b) Grounded emitter mode.

(i) *Oscillator at the Switch-on time* : The equivalent circuit for the grounded base case at the switch ON time was given in Fig. 3. Redrawing it for the grounded emitter case as in Fig. 5, we can find the relation between emitter and collector currents,

$$i_e = \alpha i_a + n i_a$$

or,

$$i_e \simeq i_a(n+1) \quad \cdots \quad (15)$$

Again referring to Fig. 3, if the transformer turns ratio for the grounded base mode is ν then

$$i_e = i_a \cdot \nu. \quad \cdots \quad (16)$$

Since however, for the same regeneration speed, i.e., for identical switch on time, i_e's should be equal for both the grounded emitter and the grounded base modes for a fixed i_a, it is clear by comparing eqns (15) and (16) that,

$$\nu = (n+1) \quad (17)$$

In fact this same result has also been given by Tendick (1956). It states that for the same speed of switching the correspondence, as shown in Fig. 6, must exist between the grounded base and the grounded emitter modes.

(ii) *Oscillator during the ON-period* : Analysis would be in the same line as in the grounded base mode. The equivalent circuit for this case during the *ON*-state is as shown in Fig. 7 in which β_0 is the grounded emitter current gain. Other notations are the same as in the grounded base mode. As before, we can write,

$$i_d = \frac{V_0 \cos \omega t}{n[r_b + \beta_0 r_e]} \left(\beta_0 - \frac{1}{n} \right) \quad \cdots \quad (18)$$

and,

$$i(t) = V_0 \sqrt{\frac{C}{L_m}} \sin \omega t. \quad \cdots \quad (4)$$

Again the pulse duration τ_e is obtained by putting $t = \tau_e$ in equation (4) and (18) and equating the two. This gives

$$\tan \omega\tau_e = \sqrt{\frac{L_m}{C}} \cdot \frac{\beta_0 n - 1}{n^2(r_b + \beta_0 r_e)}, \qquad \ldots \quad (19)$$

the amplitude of discharge is now given by,

$$A_e = V_0 \left[1 - \frac{1}{\left[1 + \frac{L_m}{C} \left[\frac{\beta_0 n - 1}{n^2(r_b + \beta_0 r_e)} \right]^2 \right]^{\frac{1}{2}}} \right] \qquad \ldots \quad (20)$$

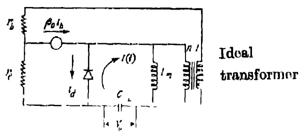


Fig. 7. Grounded emitter equivalent circuit during the ON-state of the blocking oscillator.

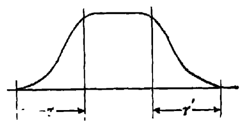


Fig. 8. Switching on and switching off times of a transistor.

Usually, $\beta_0 n \gg 1$ and hence eqn. (20) may be re-written as,

$$A_e = V_0 \left[1 - \frac{1}{\left[1 + \frac{L_m}{n^2 C} \left[\frac{\beta_0}{(r_b + \beta_0 r_e)} \right]^2 \right]^{\frac{1}{2}}} \right]. \qquad \ldots \quad (21)$$

Other things remaining constant the maximum discharge is obtained for a turns ratio determined by the condition,

$$\frac{\partial}{\partial n} (\tan \omega\tau_e) = 0$$

whence we get from ean. (19),

$$n = \frac{2}{\beta_0}. \qquad \ldots \quad (22)$$

Generally, $\beta_0 >> 1$ and hence $n << 1$, i.e., use must be made of a step up transformer. *Noting that the base is a lower impedance point than the collector the feedback stability with such a step-up transformer from collector to base will* be rather unsatisfactory and *the switching of the oscillator may therefore be quite* uncertain. To avoid this one might choose a unity transformer *ratio* as the limiting case for the grounded emitter configuration thus sacrificing a little the optimum condition of operation. The result thus obtained may be compared with those of a grounded base configuration under optimum condition with $n = 2$ in order to assess the relative excellence of the two modes as media for a condenser discharge.

EFFECT OF DELAY ON DISCHARGE

In the foregoing analysis the effect of delay was completely ignored. In a practical transistor finite times are elapsed during both the switching on and switching off process These times are of the same order of magnitude. During these periods τ and τ' the current does not remain constant but varies in the manner shown in Fig. 8 and voltage across the condenser is discharged by small amounts. A simple procedure for estimating the extent of discharge of the condenser voltage due to these currents would be to assume the existence of an additional current of magnitude equal to that of the main pulse and of duration τ—the switching on time

Diode current equations, however, are still valid provided that we allow for an additional discharge of the condenser corresponding to this delay time

Moll (1954) has given the following switch on times (τ) for the common base and the common emitter configurations.

Common base :

$$\tau = \frac{1}{\omega_{ab}} \ln \frac{I_e}{I_e - \dfrac{0.9 I_c}{\alpha_0}}. \qquad \ldots (23)$$

Common emitter :

$$\tau = \frac{1}{(1-\alpha_0)\omega_{ab}} \ln \frac{I_b}{I_b - 0.9 \dfrac{1-\alpha_0}{\alpha_0} . I_c}, \qquad \ldots (24)$$

where, I_e, I_b, I_c are at any instant the emitter, the base and the collector currents respectively.

It is obvious that in the mode of operation described above

$$\frac{I_c}{\alpha_0} = I_e$$

and

$$I_c \frac{1-\alpha_0}{\alpha_0} = I_b.$$

Equations (23) and (24) then reduce to

$$\tau = \frac{2.30}{\omega_{ab}} \simeq \frac{0.4}{f_{ab}}, \quad \ldots \quad (25)$$

and

$$\tau = \frac{2.30}{(1-\alpha_0)\omega_{\alpha b}} \simeq \frac{0.4}{f_{\alpha b}/\beta_0} \quad \ldots \quad (26)$$

respectively.

The condenser discharges by a small amount during this interval and the change in the condenser voltage due to this initial discharge is given by

$$A_i = V_0(1-\cos\omega\tau). \quad \ldots \quad (27)$$

Since $\omega\tau$ is small, $\cos\omega\tau$ can be expanded retaining only the first two terms. We thus get,

$$A_i \simeq V_0 \cdot \frac{\omega^2\tau^2}{2}. \quad \ldots \quad (28)$$

Inserting the values of τ as given by (25) and (26), we get, for the common-base,

$$A_i = 0.08\ V_0(\omega/f_{ab})^2 \quad \ldots \quad (29)$$

and for the common emitter,

$$A_i = 0.08 V_0(\beta\omega/f_{ab})2. \quad \ldots \quad (30)$$

For the typical values,

$$f_{ab} = 3.5\ \text{Mc/s}, \quad \beta_0 = 40 \text{ and } L_m = 300\ \mu H,\ C = 0.47\mu F,$$

we get from (5), (29) and () for the common base mode

$$A_i = 4.6\times10^{-3}V_0, \quad \ldots \quad (31)$$

and for the common emitter mode,

$$A_i \simeq 0.07 V_0. \quad \ldots \quad (32)$$

Eqns. (31) and (32) indicate that the effect of delay is negligible in the case of common base configuration but it is not so in the common emitter case. Hence, adding (21) and (32) the total amplitude of discharge for the common emitter configuration is found to be,

$$A = V_0\left[1.07 - \frac{1}{\left[1+\dfrac{L_m}{n^2C}\left(\dfrac{\beta_0}{r_b+\beta_0 r_e}\right)^2\right]^{\frac{1}{2}}}\right]. \quad \ldots \quad (33)$$

COMPARISON BETWEEN COMMON-BASE AND COMMON-EMITTER CONFIGURATIONS

At this stage it would be instructive to compare the performances of the common-base and common-emitter modes of operation of the blocking oscillator as the discharge element for a condenser. As was explained before, for stability of operation $n = 1$ for the common-emitter configuration. From eqn. (33) the amplitude of discharge A_1 under the condition is found to be

$$A_1 = V_0\left[1.07-\frac{1}{\left[1+\frac{L_m}{C}\left(\frac{\beta_0}{r_b+\beta_0 r_e}\right)^2\right]^{\frac{1}{2}}}\right] \qquad \dots (34)$$

For the common-base mode the amplitude for maximum discharge is given by eqn. (14). Denoting this by A_2 we have from (14) and (4),

$$\frac{A_1}{A_2}=\frac{1.07-\dfrac{1}{\left[1+\dfrac{L_m}{C}\left\{\dfrac{\beta_0}{r_b+\beta_0 r_e}\right\}^2\right]^{\frac{1}{2}}}}{1-\dfrac{1}{\left[1+\dfrac{L_m}{C}\left\{\dfrac{\alpha_0^2}{4[r_e+r_b(1-\alpha_0)]}\right\}^2\right]^{\frac{1}{2}}}}. \qquad \dots (35)$$

Taking $\alpha_0 \simeq 1$ and $\dfrac{1}{1-\alpha_0} \simeq \beta_0$, eqn.(35) is reduced to

$$\frac{A_1}{A_2}=\frac{1.07-\dfrac{1}{\left[1+\dfrac{L_m}{C}\left\{\dfrac{\beta_0}{r_b+\beta_0 r_e}\right\}^2\right]^{\frac{1}{2}}}}{1-\dfrac{1}{\left[1+\dfrac{L_m}{C}\left\{\dfrac{\beta_0}{4(r_b+\beta_0 r_e)}\right\}^2\right]^{\frac{1}{2}}}}, \qquad \dots (36)$$

or,

$$\frac{A_1}{A_2}\simeq\frac{1-\dfrac{1}{\left[1+\dfrac{L_m}{C}\left\{\dfrac{\beta_0}{r_b+\beta_0 r_e}\right\}^2\right]^{\frac{1}{2}}}}{1-\dfrac{1}{\left[1+\dfrac{L_m}{C}\left\{\dfrac{\beta_0}{4(r_b+\beta_0 r_e)}\right\}^2\right]^{\frac{1}{2}}}} \qquad \dots (37)$$

which is always greater than unity. Hence, we find from eqn. (37) that, compared with the grounded-base configuration, a grounded-emitter blocking oscillator should give a wider voltage swing during the discharge of a condenser even though it cannot be operated under the optimum condition. From the point of view of voltage swing the use of this latter mode is then seen to be more advantageous The exact margin of advantage thus obtainable is, however, dependent on the value of L_m/C.

USE OF A FREE-RUNNING BLOCKING OSCILLATOR AND GENERATION OF STAIRCASE WAVEFORM

In the foregoing analysis considerations had been restricted to a single shot blocking oscillator For this the condenser is not fully discharged during a pulse but the voltage across the condenser at the end of discharge is

$$V_{c\tau} = V_0 \cos \omega\tau \qquad \ldots \quad (9)$$

With the charging circuit off or with a charging circuit of sufficiently large time constant this voltage will be maintained across the condenser after the blocking oscillator switches to the *OFF* state. An interesting possibility arises if instead of a single shot oscillator, use is made of a free running one having a low duty cycle. After a time equal to the quiescent period of the blocking oscillator, the condenser will start discharging again If the condenser does not receive any appreciable additional charge during this period the initial voltage across it for this second phase of discharge would be $V_0 \cos \omega\tau$ instead of V_0 This process would repeat itself until the condenser has been completely discharged. In other words, the condenser will discharge in several steps giving rise to a staircase waveform. The condenser voltages V_1, $V_2 \ldots$, V_r, at the end of the 1st, 2nd,..., r-th phase of the discharge are given by

$$V_1 = V_0 \cos \omega\tau$$

$$V_2 = V_1 \cos \omega\tau = V_0 \cos^2 \omega\tau$$

$$\ldots \quad \ldots \quad \ldots \quad \ldots$$

$$V_r = V_{r-1} \cos \omega\tau = V_0 \cos^r \omega\tau, \qquad \ldots \quad (38)$$

so that

$$\frac{V_r}{V_0} = \cos^r \omega\tau. \qquad \ldots \quad (39)$$

The number of steps required for the voltage to discharge to 10% of its initial value V_0 is obtained from the relation

$$\cos^r \omega\tau = 0.1$$

or,

$$r = -1/\log_{10} \cos \omega\tau. \qquad \ldots \quad (40)$$

EXPERIMENTAL RESULTS AND DISCUSSIONS

In this section we would describe the results of experiments on condenser discharge using single shot blocking oscillators of both the grounded base and the grounded-emitter mode The results would be compared with the theoretical relations derived in the preceding sections

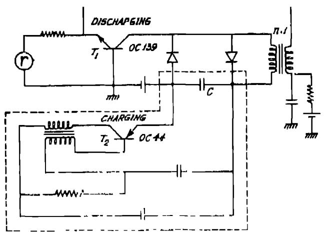


Fig 9(a). Circuit details of the experimental blocking oscillator in the grounded base mode

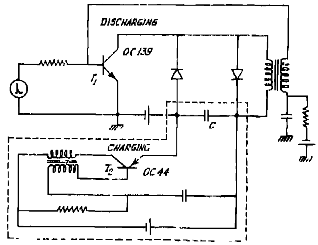


Fig. 9(b) Circuit details of the experimental blocking oscillator in the grounded emitter mode

The circuit details of the experimental blocking oscillators of the grounded base and grounded-emitter modes are given in Figs. 9(a) and 9(b). In these transistors OC139 are in the blocking oscillator discharging circuit under investigation and OC44 in the charging circuit. T_1 being an $n-p-n$ transistor the triggering is achieved by applying a negative pulse at the emitter point in Fig 9(a) and positive pulse at the base in Fig. 9(b). Transistor T_2 charges the condensor C (see Appendix)

(i) *Common-base mode*

(a) *Variation of amplitude with C* · Study of the variation of amplitude A with C using the circuit shown in Fig 9(a) was made for $V_0 = 3$ volts with two different values of n, viz., 2 and 5. Experimental values of the amplitude for six different values of C are given in column 3, Tables I and II.

Referring to eqn. (11) and expanding we can write,

$$A = V_0 \frac{L_m}{2C} \left[\frac{(\alpha_0 n - 1)}{n^2[r_e + r_b(1-\alpha_0)]} \right]^2, \quad \ldots \quad (41)$$

or,

$$C.A \simeq \frac{V_0 L_m}{2} \left[\frac{\beta_0(n-1)}{n^2(r_b + \beta_0 r_e)} \right]^2, \quad \ldots \quad (42)$$

which is a constant for a given value of n and V_0. Column 4 in Tables I and II confirm the expectation. Now, a direct measurement gave $L_m = 300\mu H$, $\beta_0 = 40$, $r_b = 100$ ohms and $r_e = 30$ ohms. The last columns of the tables give the product $C.A.$ as obtained from eqn. (42) and these values.

These are seen to agree closely with the experimental values in columns 4.

TABLE I

n	$C(\mu F)$	A (volts)	$C.A.$	$C.A.$ (calculated)
2	0.1	0 28	0.028	0 027
	0.23	0 12	0.028	
	0.33	0 09	0.030	
	0 47	0.06	0.028	
	0 57	0 05	0 029	
	0.94	0.03	0.028	

TABLE II

n	C (μF)	A (volts)	$C.A.$	$C.A.$ (calculated)
5	0.1	0 114	0 011	0.011
	0.23	0 045	0 011	
	0 33	0 030	0 010	
	0 47	0.024	0 011	
	0.57	0.018	0 010	
	0 94	0 012	0.011	

(b) *Variation of amplitude with n* It is also of interest to study the variation of A with the turns ratio n for a fixed value of C. Experimental results obtained with $C = 0.47\mu F$ are shown in column 3, Table III. Calculated values, based on eqn. (41) and on the simplifying assumptions $\alpha_0 \simeq 1$, $(1-\alpha_0) \simeq 1/\beta_0$. and given in the last column are in fair agreement with these results.

TABLE III

C (μF)	n	A (volts)	A (volts) calculated
0 47	5	0.024	0 023
	3	0 042	0 045
	2	0.060	0 057
	1	0	0

(ii) *Common-emitter mode*

(a) *Variation of amplitude with C* : Experiments on the common emitter mode were carried out with the circuit shown in Fig. 9(b) with $n = 1$. Table IV, columns 3 and 4 give the observed and calculated values of A for different values of C. Calculations were made using eqn. (33), the numerical values of the various parameters being the same as those mentioned in Sec. 3(i) for the common-base mode. Again, the experimental results seem to agree closely with the calculated values. It may be noted that in eqn. (33) the second term under the square root sign is high compared to unity and hence for this case $C.A. \neq a$ constant for a given value of n.

TABLE IV

n	C (μF)	Amplitude (volts)	Amplitude (volts) calculated
1	0.23	1.20	1.17
	0.33	1.00	0.99
	0.47	0.87	0.84
	0.57	0.76	0.75
	0.94	0.57	0.57

(b) *Variation of amplitude with n:* Table V gives the experimental and calculated results for the variation of amplitude with n for $C = 0.47\mu F$ for the common-emitter configuration. Calculations are again based on eqn. (33), with the values mentioned before Agreement between the experimental and the theoretical values is once again very satisfactory.

TABLE V

C (μF)	n	A (volts)	A (volts) calculated
0.47	1	0.87	0.84
	2	0.42	0.42
	3	0.36	0.33
	5	0.24	0.25

(iii) *Comparison between common-emitter and common-base configurations*

To check eqn. (37), Tables I and IV were used to obtain the experimental values of A_1/A_2 for different values of C. These values are recorded in column 2, Table VI. In this A_1 corresponds to amplitude for $n = 1$ for the common-emitter and

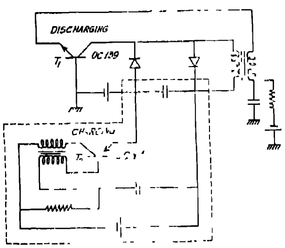


Fig. 10(a). Grounded base configuration of the staircase waveform generator

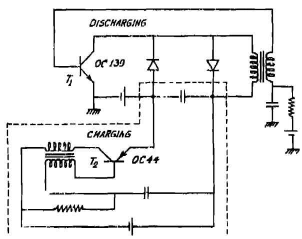


Fig. 10(b) Grounded emitter configuration of the staircase waveform generator.

A_2 to the configuration for the optimum condition $n = 2$ for the common base configuration. Calculated values of A_1/A_2, as given by eqn. (37), are shown in column 3, Table VI. The extent of agreement between the two sets of values is obviously quite satisfactory.

TABLE VI

C (μF)	A_1/A_2 experimental	A_1/A_2 calculated
0 23	10 0	9 8
0.33	11 1	12.4
0 47	14 5	14.0
0 57	15 2	15.0
0.94	19 0	19 0

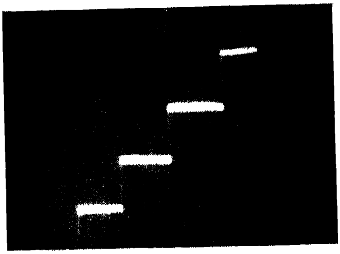


Fig 11 Staircase waveform with equal steps

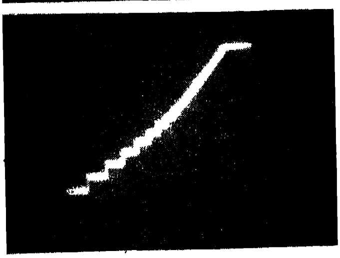


Fig 12. Staircase waveform with unequal steps.

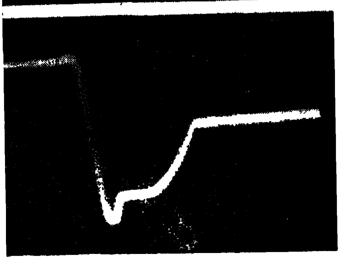


Fig 13. Trailing edge of a step of the waveform in fig. 11.

(iv) *Generation of staircase waveform*

For generation of staircase waveform Figs. 9(a) and 9(b) were modified by biasing the discharging transistor T_1 in the forward direction and withdrawing the triggering arrangements, [Figs. 10(a) and (10(b)]. Under this condition they functioned as free-running oscillators. The general pattern of the condenser discharge generating staircase waveform is shown in Figs. 11 and 12 It is clear that if the discharge in a given step is restricted to a rather smaller value as in the case of Fig. 11, the successive steps become fairly equal This is to be expected from eqn. (39) which requires that for small values of $\omega\tau$

$$\frac{V_r}{V_0} \simeq \left(1 - \frac{r\omega^2\tau^2}{2}\right) \qquad \ldots \quad (43)$$

Also, the trailing end of each step should conform to eqn. (6) and this is illustrated in Fig. 13 which is merely a record of the waveform shown in Fig. 11 on an expanded time base.

CONCLUSION

A detailed study on the discharge of condenser by a transistorized blocking oscillator has been made. The experimental results have been found to agree well with the result of theoretical analysis From the point of view of voltage swing during discharge, a grounded-emitter mode of operation appears to be satisfactory even though it cannot be operated under optimum conditions Also, by referring to Figs. 6(a) and (b) it is seen that identical speed of switching is obtained for $n = 1$ for the grounded emitter and $n = 2$ for the grounded base grounded modes respectively which means that speed of operation is not sacrificed in using a emitter oscillator although it gives a greater voltage swing.

An incidental development of the study is the possibility of the generation of staircase waveform with the advantage of having adjustable number of steps in a given time. This may be useful in counter circuits and in the quantization of information.

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APPENDIX

The charging circuit as mentioned in the text is shown inside the dotted line enclosure in Figs. 9(a), 9(b), 10(a) and 10(b). It may be seen by referring to these figures that it is another blocking oscillator, the regeneration of which is provided by the transformer at the collector of the transistor T_2. The condenser C to be charged is placed in the emitter circuit of T_2.

On completing a discharge stroke, transistor T_1 remains quiescent so that when T_2 charges the condenser C there is no loading due to T_1. Similarly, in between the quiescent periods of T_2 when T_1 discharges the condenser C there is also no loading effect present. Thus, it follows that working of T_1 and T_2 isi ndependent of each other.

It may be shown from a simple analysis of the charging circuit that under such conditions, the voltage to which the condenser C may be charged is given by

$$V_0 = \frac{nE}{n+1} \tag{44}$$

where V_0 = voltage to which C is charged,

E = H.T. voltage of T_2,

n = turns ratio of the transformer at the collector of T_2.

In our case, we choose, $E = 6$ volts and $n = 1$, so that V_0 becomes equal to 3 volts.